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(54) **DIAMOND IMPREGNATED BIT WITH AGGRESSIVE FACE PROFILE**

(75) Inventors: **Christian M. Lambert**, Draper, UT (US); **Michael D. Rupp**, Murray, UT (US)

(73) Assignee: **Longyear TM, Inc.**, South Jordan, UT (US)

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E21B 10/567 (2006.01)
E21B 10/02 (2006.01)

(52) **U.S. Cl.**

CPC ***E21B 10/02*** (2013.01); *Y10T 29/4998* (2015.01); ***E21B 10/48*** (2013.01)

(58) **Field of Classification Search**

CPC E21B 10/02; E21B 10/48; E21B 10/567
USPC 175/403, 405.1; 166/242.1
See application file for complete search history.

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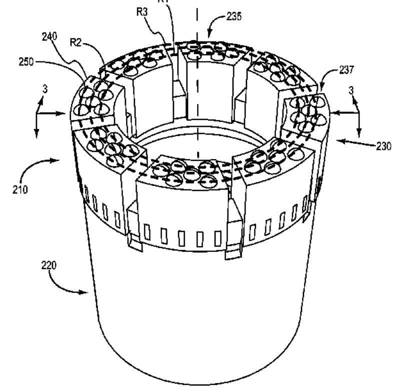
Primary Examiner — Catherine Loikith

(74) *Attorney, Agent, or Firm* — Ballard Spahr LLP

(57) **ABSTRACT**

A drill bit includes a crown defining a central axis. The crown includes at least one segment. The segment includes a planar portion and a plurality of surface features continuous with and extending away from the planar portion. The surface features are discontinuous within the segment with respect to a first arced path defined at a first radial distance from the central axis.

18 Claims, 5 Drawing Sheets



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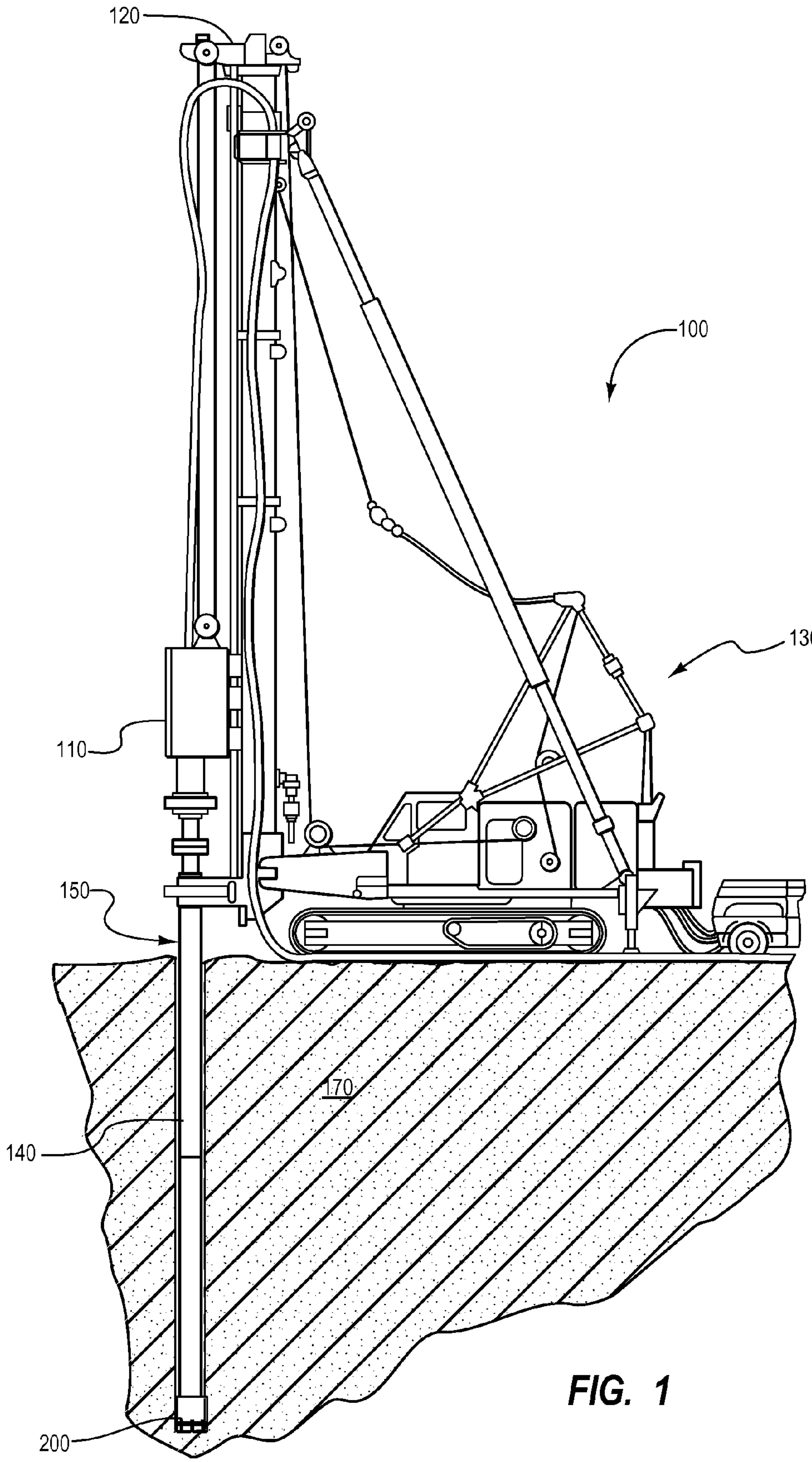

FIG. 1

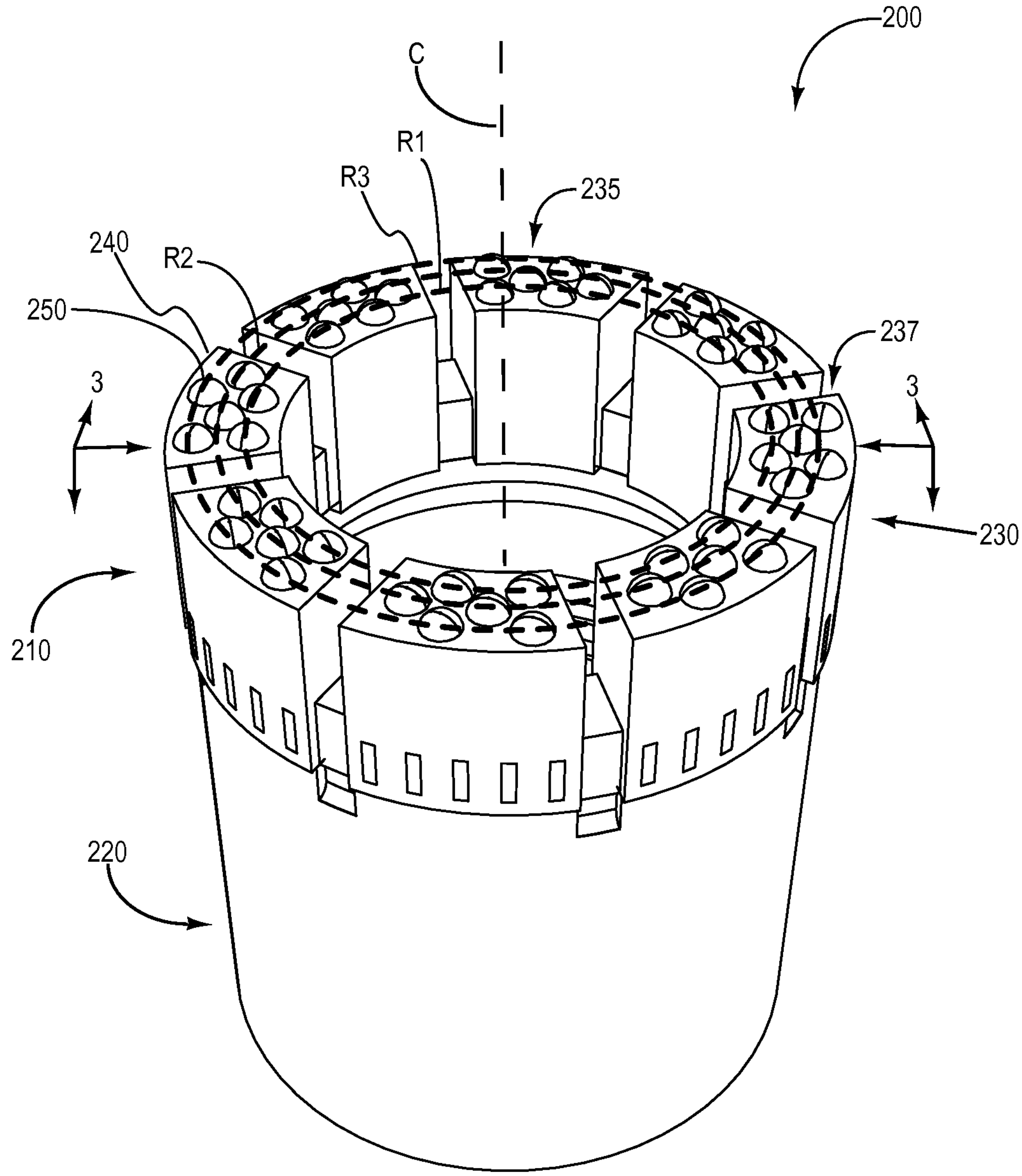

FIG. 2

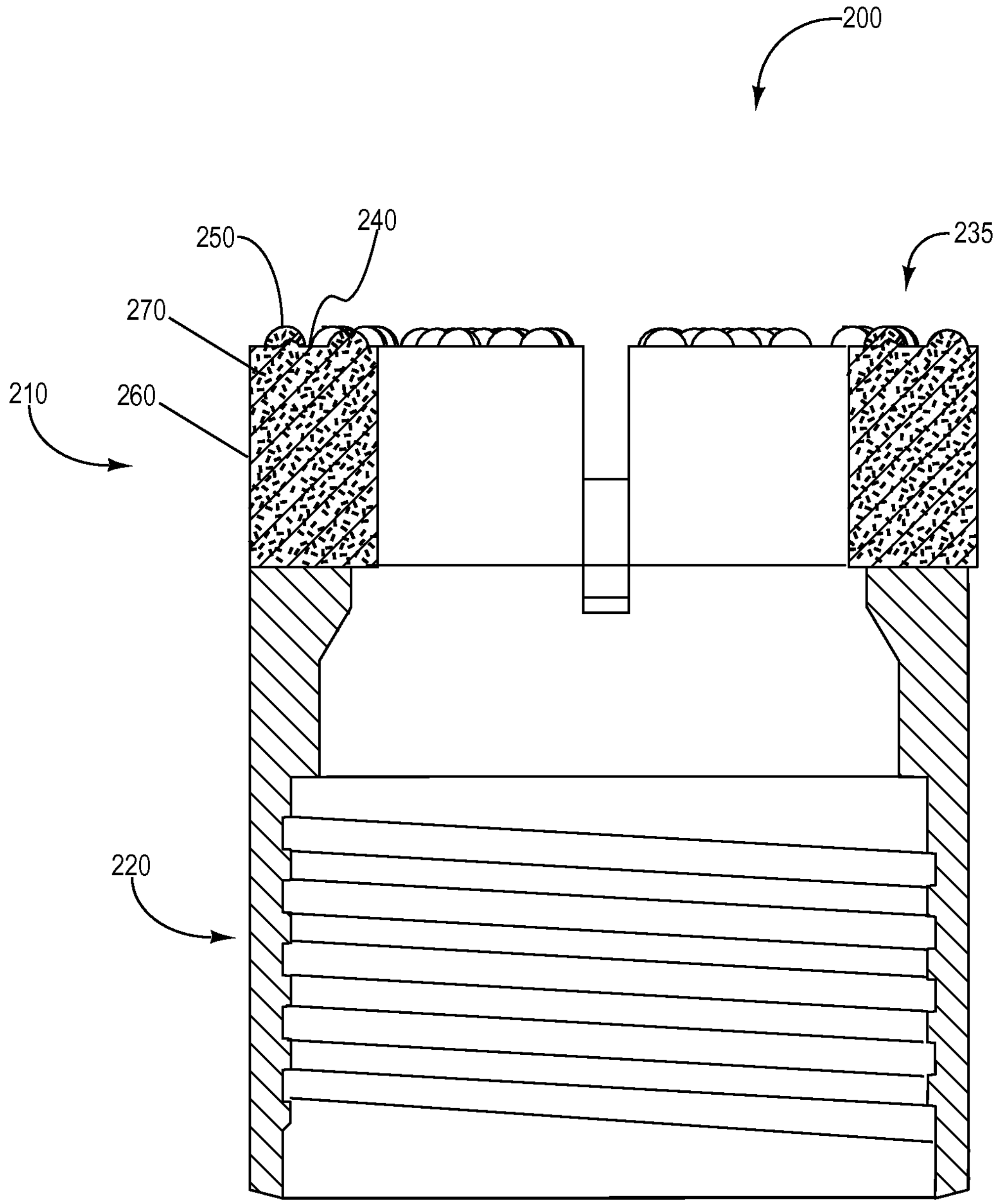

FIG. 3

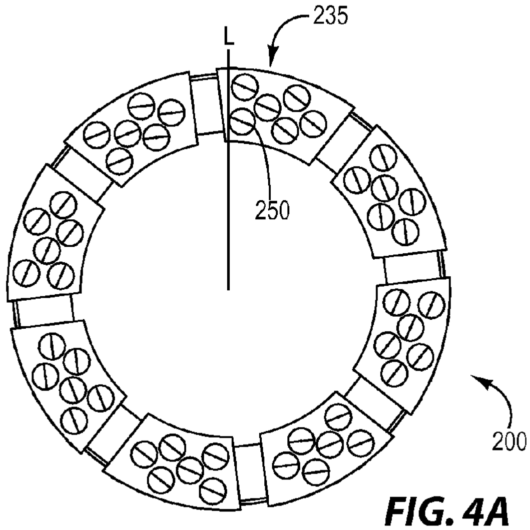

FIG. 4A

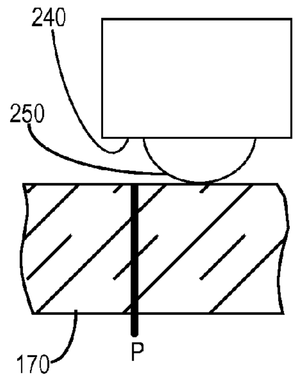

FIG. 4B

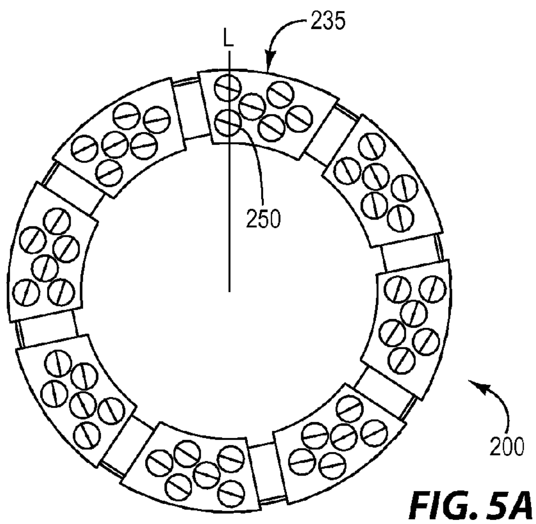

FIG. 5A

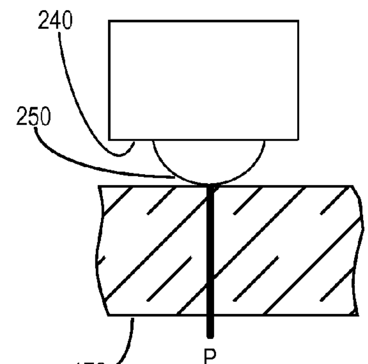

FIG. 5B

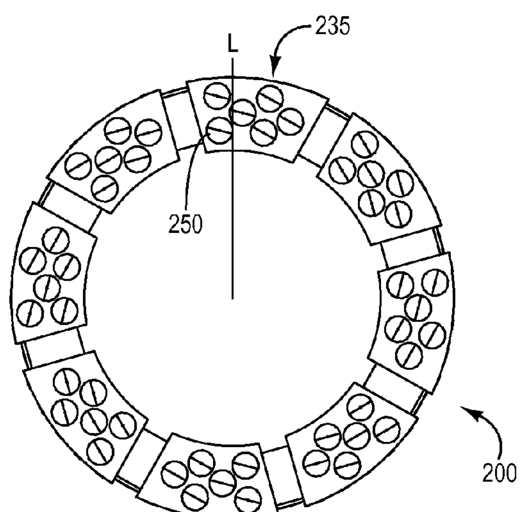

FIG. 6A

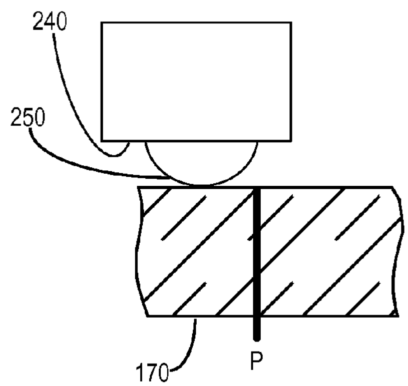

FIG. 6B

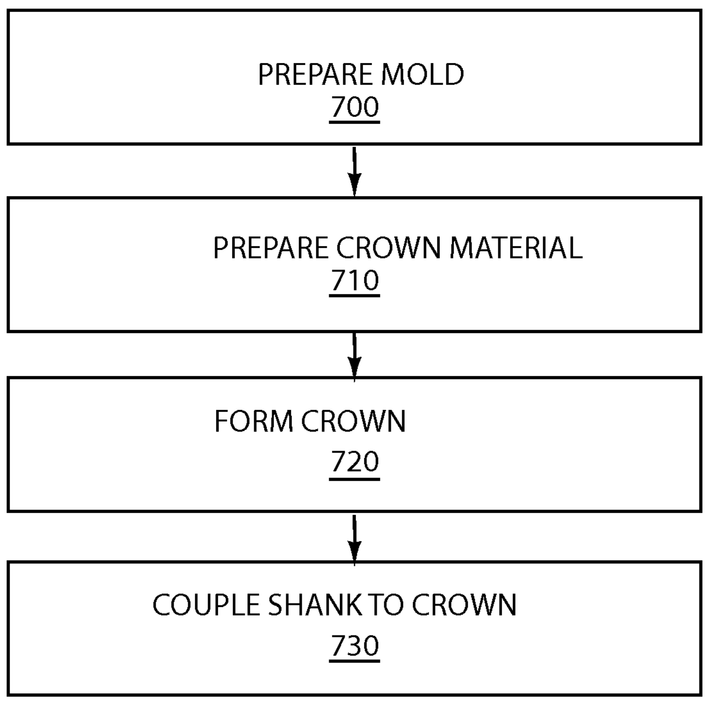
PREPARE MOLD
700
PREPARE CROWN MATERIAL
710
FORM CROWN
720
COUPLE SHANK TO CROWN
730

FIG. 7

DIAMOND IMPREGNATED BIT WITH AGGRESSIVE FACE PROFILE

CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims the benefit of prior-filed U.S. Provisional Application 61/233,952 filed Aug. 14, 2009 and entitled "DIAMOND IMPREGNATED BIT WITH AGGRESSIVE FACE PROFILE," the disclosure of which is hereby incorporated by reference in its entirety.

BACKGROUND

1. The Field of the Invention

This application relates generally to drill bits and methods of making and using such drill bits. In particular, this application relates to impregnated drill bits with aggressive face-profiles, as well as to methods for making and using such drill bits.

2. The Relevant Technology

While many different drilling processes are used for a variety of purposes, in most drilling processes a drill head applies axial forces (feed pressure) and rotational forces to drive a drill bit into a formation. More specifically, a bit is often attached to a drill string, which is a series of connected drill rods coupled to the drill head. The drill rods are assembled section by section as the drill head moves and drives the drill string deeper into the desired sub-surface formation. One type of drilling process, rotary drilling, involves positioning a rotary cutting bit at the end of the drill string. The rotary cutting bit often includes cutters that are distributed across the face of the rotary cutting bit.

Bits can be impregnated with diamonds so that they can be used to cut hard formations and/or to increase the durability of the bit. The part of the bit that performs the cutting action, sometimes referred to as a face, is generally formed of a matrix that contains a powdered metal or a hard particulate material, such as tungsten carbide. This material is sometimes infiltrated with a binder, such as a copper alloy. The matrix and binder associated with the face are mixed with diamond crystals or some other form of abrasive cutting media. As the tool grinds and cuts the desired materials, the matrix and binder erode and expose new layers of the diamond crystal (or other cutting media) so that a sharp surface is always available for the cutting process.

In order for a new bit to drill a formation, some portion of the matrix and binder often must be eroded away in order to expose a sufficient amount of the diamond to allow the diamond to cut the formation. Accordingly, often there is a break-in period for a bit after the bit is placed in rotating contact with a formation as the matrix wears to expose a sufficient amount of the diamonds for effective cutting. Such a process can increase the time associated with the corresponding drilling operations, and hence costs. This delay can be exacerbated if the bit is used in relatively soft formations as it may require a relatively long time to expose sufficient diamonds for effective cutting.

One approach to expose sufficient diamonds rapidly is to prepare the surface of the bit, such as by performing an initial grinding operation. In such an operation, the bit can efficiently cut as it rotates shortly after the bit is placed in contact with the formation. However, such a process still introduces additional time to the entire drilling operation, as well as the complexity associated with an additional step. Alternatively, this grinding process can be performed by the manufacturer of the bit, adding additional process time and cost.

BRIEF SUMMARY OF THE INVENTION

A drill bit includes a crown defining a central axis. The crown includes at least one segment. The segment includes a planar portion and a plurality of surface features continuous with and extending away from the planar portion. The surface features are discontinuous within the segment with respect to a first arced path defined at a first radial distance from the central axis.

In order for a new bit to drill a formation, some portion of the matrix and binder often must be eroded away in order to expose a sufficient amount of the diamond to allow the diamond to cut the formation. Accordingly, often there is a break-in period for a bit after the bit is placed in rotating contact with a formation as the matrix wears to expose a sufficient amount of the diamonds for effective cutting. Such a process can increase the time associated with the corresponding drilling operations, and hence costs. This delay can be exacerbated if the bit is used in relatively soft formations as it may require a relatively long time to expose sufficient diamonds for effective cutting.

Additional features and advantages of exemplary implementations of the invention will be set forth in the description which follows, and in part will be obvious from the description, or may be learned by the practice of such exemplary implementations. The features and advantages of such implementations may be realized and obtained by means of the instruments and combinations particularly pointed out in the appended claims. These and other features will become more fully apparent from the following description and appended claims, or may be learned by the practice of such exemplary implementations as set forth hereinafter.

BRIEF DESCRIPTION OF THE DRAWINGS

The following description can be better understood in light of the Figures, in which:

FIG. **1** illustrates a drilling system according to one example;

FIG. **2** illustrates a perspective view of a drill bit according to one example;

FIG. **3** illustrates a cross-sectional view of a drill bit according to one example;

FIG. **4**A illustrates an end view of a drill bit according to one example;

FIG. **4**B illustrates an exemplary interaction between a surface feature and a formation at a reference point according to one example;

FIG. **5**A illustrates an end view of a drill bit according to one example;

FIG. **5**B illustrates an exemplary interaction between a surface feature and a formation at a reference point according to one example;

FIG. **6**A illustrates an end view of a drill bit according to one example;

FIG. **6**B illustrates an exemplary interaction between a surface feature and a formation at a reference point according to one example; and

FIG. **7** is a flowchart illustrating a method of forming a drill bit according to one example.

Together with the following description, the Figures demonstrate and explain the principles of the apparatus and methods for using the drill bits. In the Figures, the thickness and configuration of components may be exaggerated for clarity. The same reference numerals in different Figures represent the same component.

DETAILED DESCRIPTION

Drill bits, methods of using drill bits, and methods of producing drill bits are described herein. In at least one example, the drill bits include a cutting face with a generally planar surface and surface features continuously formed with and extending from the planar surface. The surface features have gaps between them on the generally planar surface that cause the surface features to apply variable contact stresses to a formation as the drill bit rotates. Such a configuration can allow the drill bit to quickly fatigue the material, which in turn can cause the material to break away from the adjacent material more quickly. Accordingly, the surface features can increase the cutting speed of the drill bit.

In at least one example, the cutting face can be divided into segments in which adjacent segments are separated by water channels defined in the otherwise generally planar portion of the cutting face. In such an example, one or more of the segments can include surface features that are discontinuous or are otherwise separated by gaps in an arc on the cutting face which is defined at a given radial location. One such configuration can be provided by cutting features that are partially ellipsoid in shape, such as generally hemispherical.

The following description supplies specific details in order to provide a thorough understanding. Nevertheless, the skilled artisan would understand that the apparatus and associated methods of using the apparatus can be implemented and used without employing these specific details. Indeed, the apparatus and associated methods can be placed into practice by modifying the illustrated apparatus and associated methods and can be used in conjunction with any other apparatus and techniques conventionally used in the industry. For example, while the description below focuses on rotary drill bits for obtaining core samples, the apparatus and associated methods could be equally applied in other drilling apparatuses and processes, such as diamond core drill bits and other vibratory and/or percussive drill systems.

FIG. **1** illustrates a drilling system **100** that includes a drill head assembly **110**. The drill head assembly **110** can be coupled to a mast **120** that in turn is coupled to a drill rig **130**. The drill head assembly **110** is configured to have a drill rod **140** coupled thereto. The drill rod **140** can in turn couple with additional drill rods to form a drill string **150**. In turn, the drill string **150** can be coupled to a drill bit **200** configured to interface with the material to be drilled, such as a formation **170**.

In at least one example, the drill head assembly **110** is configured to rotate the drill string **150**. In particular, the rotational rate of the drill string **150** can be varied as desired during the drilling process. Further, the drill head assembly **110** can be configured to translate relative to the mast **120** to apply an axial force to the drill head assembly **110** to force the drill bit **200** into the formation **170** during a drill process.

In at least one example, the drill bit **200** includes a cutting face with a generally planar surface and surface features continuously formed with and extending from the planar surface. The surface features have gaps between them on the generally planar surface that cause the surface features to apply variable contact stresses to a formation as the drill bit **200** rotates. Such a configuration can allow the drill bit **200** to quickly fatigue the material, which in turn can cause the material to break away from the adjacent material more quickly. Accordingly, the surface features can increase the cutting speed of the drill bit **200**.

In at least one example, the cutting face can be divided into segments in which adjacent segments are separated by water channels defined in the otherwise generally planar portion of the cutting face. In such an example, one or more of the segments can include surface features that are discontinuous or are otherwise separated by gaps in an arc on the cutting face that is defined at a given radial location. One such configuration can be provided by cutting features that are partially ellipsoid in shape, such as generally hemispherical. One exemplary drill bit will now be discussed in more detail with reference to FIG. **2**.

FIG. **2** illustrates a perspective view of the drill bit **200** introduced with reference to FIG. **1**. The crown **210** and/or the drill bit **200** define a central axis C. As described herein, radial aspects, orientations, or measures will be described as being transverse to the central axis C. As illustrated in FIG. **2**, the drill bit **200** generally includes a crown **210** secured to a shank **220**.

The crown **210** may also include a cutting face **230** formed from a plurality of segments **235**. The segments **235** can be separated by water channels **237** formed in the crown **210** that extend radially through adjacent segments **235**. Each segment **235** includes a generally planar portion **240** and a plurality of surface features **250** continuous with and extending away from the planar portion **240** of the cutting face **230**.

A portion of the surface features **250** that contacts a formation can have an at least partially arcuate cross-sectional shape. In at least one example, the surface features **250** can have a three-dimensionally arcuate cross-sectional shape. Such a configuration can result in a surface feature that is some portion of an ellipsoid. Such shapes can include, without limitation, surface features that are shaped as some portion of a sphere or a spheroid. One example of a partial spheroid is a hemisphere.

Such a configuration results in discontinuously raised portions at various radial positions on the segments **235**. The surface features **250** can be arranged in any number of configurations that include repeating patterns and/or random arrangements on the segments **235**. In the example shown, the surface features **250** are arranged at three radial positions **R1**, **R2**, **R3** on each of the segments **235**. In other examples, the more or less surface features **250** can be arranged at any number of radial positions. The number of radial positions can also vary between segments. Further, the surface features **250** can also be randomly and/or unevenly distributed about the cutting face **230** as desired.

For ease of reference, the radial positions shown in FIG. **2** will be described. In the illustrated example, the surface features **250** are shown having approximately the same widths or diameters at each radial position. For example, surface features **250** positioned at radial position **R1** have generally the same width or diameter as surface features **250** at radial positions **R2** and **R3**. However, the surface features **250** may also have different diameters at each of the radial positions **R2** and **R3**. In at least one example, surfaces features **250** at **R1** may have a larger diameter than surface features **250** at radial position **R2** and/or **R3**. Similarly, surface features **250** at radial position **R2** may have a larger diameter than surface features **250** positioned at radial position **R3**. Accordingly, surface features **250** positioned nearer the central axis C may have larger diameters than those positioned further from the central axis C. It will be appreciated that the inverse may also be true as desired or that diameters of the surface features may vary in any number of ways.

As also shown in FIG. **2**, the surface features **250** may be positioned at an angular offset with respect to surface features **250** at adjacent radial positions. In particular, surface features **250** at radial position R**2** may be angularly offset from surface features at adjacent radial positions R**1** and R**2**.

As shown in FIG. **2**, the configuration of the segment **235** results in gaps or spaces between adjacent surface features **250** at a given radial position. Such a configuration results in discontinuous contact at a given location on a formation as the drill bit **200** rotates. This in turn can cause or generate fluctuating stress at that location, which can cause the material at that location to fatigue and fail rapidly, thereby causing rapid cutting of the formation. In particular, in at least one example, abrasive particles embedded in a matrix cut the material. One exemplary configuration of a matrix and abrasive materials will now be discussed in more detail, followed by a discussion of a cutting operation using circumferentially discontinuous surface features.

FIG. **3** illustrates a cross-sectional view of the drill bit **200** taken along section **3-3** of FIG. **2**. FIG. **3** illustrates that the surface features **250** extend from and are integrally formed with planar portion **240**. As a result, the surface features **250** and planar portion **240** form a single integrated crown **210**. As illustrated in FIG. **3**, both the planar portion **240** and the surface features **250** include a matrix material **260** bonded to the shank **220** by a binder material (not shown). Further, as shown in FIG. **3**, the matrix material **260** can continuously form a substantial portion of the outer shape of the crown **210**.

Abrasive particles **270**, such as synthetic diamond particles, other types of diamonds, and/or other types of abrasive particles are distributed within and supported by the matrix **260**. In at least one example, the distribution of abrasive particles **270** is substantially uniform between the surface features **250** and the crown **210**. Such a configuration can reduce or eliminate a transition area or boundary between the crown **210** and the surface features **250**.

FIGS. **4**A-**6**B illustrates the drill bit **200** in close detail in a drilling environment within a representative formation **170** and with respect to a reference point P on the formation **170**. In particular, FIGS. **4**A, **5**A, and **6**A illustrate the rotation of the drill bit **200** relative to a stationary point P and FIGS. **4**B, **5**B, and **6**B illustrate the interaction with a single surface feature **250** with the formation **170** and with the reference point P. Line L illustrates a stationary line, which is referenced to show angular displacement of the drill bit **200** and reference point P is on the line L.

As the drill bit **200** rotates, successive surface features **250** on each segment **235** at a given radial position on the drill bit **200** come in and out of contact with the reference point P. An exemplary interaction is illustrated in FIGS. **4**B, **5**B, and **6**B. In particular, in the position shown in FIG. **4**B a relatively small area, if any, of the surface feature **250** is in contact with the reference point P as a gap between surface features **250** is positioned at an axially proximal position relative to the reference point P. In such a position, the contact stress the surface feature **250** (FIG. **4**B) applies to the reference point can be at or near a minimum.

Continued rotation of the drill bit **200** and an axial force applied to the drill bit **200** causes increasing contact between the surface feature **250** and the reference point P until the contact is at a maximum as shown in FIG. **5**B. The increasing contact results in increasing contact stress until a center of the surface feature **250** is axially aligned with the reference point P. At this point, the contact stress the surface feature **250** applies to the reference point P can be at or near a maximum value.

Continued rotation to the relative positions shown in FIGS. **6**A and **6**B results in decreasing contact and a corresponding decrease in contact stress until the contact stress returns to a minimum while a gap between adjacent features is axially aligned with the point. As a result, the configuration of the drill bit **200** allows the drill bit **200** to apply varying contact stress at various radial positions within each segment **235**, cyclically varying the contact stresses applied by each segment **235**. Varying contact stresses can result in fatigue at those various locations, which in turn can cause the material to fail more quickly than a relatively constant contact stress. Such a configuration can result in the drill bit **200** cutting more quickly than other bits.

Any suitable method can be used to form drill bits having a face made up of one or more segments in which discontinuous surface features are formed at one or more radial positions on the segments. FIG. **7** illustrates one exemplary method for forming a drill bit. As illustrated in FIG. **7**, the method may begin at step **700** by forming a mold. The mold may be formed from a material that is able to withstand the heat to which the drill bit will be subjected to during a heating process. In at least one example, the mold may be formed from carbon. The mold is shaped to form a pattern for the drill bit. Accordingly, the pattern formed in the mold may correspond to the negative of the final shape of the crown. Accordingly, the pattern may define a negative of a crown with the surface features configured as described above. Thus, the crown pattern may define a central axis. The crown pattern may also have a recess defined therein defining a generally planar portion and a plurality of surface feature patterns extending away from the generally planar portion in which the surface features are discontinuous within the segment with respect to a first arced path defined at a first radial distance from the central axis.

Crown material may then be prepared at step **710**. The crown may be formed by mixing cutting particles with a matrix material and a binder material. Further, the cutting materials may be mixed with the matrix material and binder material in such a manner that each of the materials is uniformly distributed through the resulting mixture. Any suitable matrix material may be used. Matrix materials may include durable materials, including metallic materials such as tungsten carbide. Similarly, any binder materials may be used, including metallic materials such as copper and copper alloys. The cutting materials may include abrasive materials or other materials that are able to cut an intended substrate. Suitable materials may include diamonds, such as synthetic and/or natural diamonds, including powders of the same.

The crown of the drill bit at step **720** may then be formed by putting the mixture of matrix material and cutting particles into the mold to cover both the surface features and the generally planar surface. Then the material may be pressed into the mold.

Thereafter, at step **730** a shank may be coupled to the crown. In at least one example, a shank may be coupled to the crown by placing the shank in contact with the mold and with the crown in particular. Additional matrix, binder materials, and/or flux may then be added to the mold in contact with the crown as well as the shank to complete initial preparation of the drill bit. Final preparation may optionally include subjecting the heat and/or pressure to finally prepare the bit. Other additional steps may be undertaken as desired as well.

In addition to any previously indicated modification, numerous other variations and alternative arrangements may be devised by those skilled in the art without departing from the spirit and scope of this description, and appended claims are intended to cover such modifications and arrangements. Thus, while the information has been described above with particularity and detail in connection with what is presently deemed to be the most practical and preferred aspects, it will be apparent to those of ordinary skill in the art that numerous modifications including, but not limited to, form, function, manner of operation and use may be made without departing from the principles and concepts set forth herein. Also, as used herein, examples are meant to be illustrative only and should not be construed to be limiting in any manner.

The invention claimed is:

1. A drill bit, comprising:

a crown having a distal portion and defining a central axis,

at least one fixed segment formed in the distal portion of the crown, each segment being spaced from the central axis of the crown a predetermined distance and comprising:

a planar portion forming a distal surface, wherein the planar portion of each segment is positioned transverse to the central axis of the crown; and

a plurality of surface features continuous with and extending distally away from a portion of the planar portion of each segment,

wherein the plurality of surface features comprises at least a first and a second plurality of surface features, wherein the first plurality of surface features are discontinuous and spaced apart within the segment with respect to a first arced path and have a center point defined at a first radial distance from the central axis of the crown, wherein the second plurality of surface features are discontinuous and spaced apart within the segment with respect to a second arced path and have a center point defined at a second radial distance from the central axis, wherein portions of the first and second plurality of surface features radially overlap, wherein the plurality of surface features and at least the planar portion of each segment are integrally formed of a selected matrix material, the selected matrix material comprising a matrix and a plurality of abrasive particles within the matrix, wherein each surface feature of the drill bit consists solely of the selected matrix material, and

wherein the matrix of the selected matrix material is configured to erode to expose the abrasive particles within the matrix.

2. The drill bit of claim **1**, wherein at least one surface feature of the plurality of surface features is at least partially ellipsoid in shape.

3. The drill bit of claim **2**, wherein at least one surface feature of the plurality of surface features is generally hemispherical.

4. The drill bit of claim **2**, wherein a major axis of each at least partially ellipsoid shaped surface feature is positioned at an angle with respect to a radian extending from the central axis.

5. The drill bit of claim **1**, wherein the abrasive particles of the selected matrix material comprise diamond particles.

6. The drill bit of claim **1**, wherein the at least one segment of the crown comprises a plurality of segments, adjacent segments of the plurality of segments being separated by a respective waterway.

7. The drill bit of claim **1**, wherein the planar portion and the plurality of surface features of each segment of the crown have a substantially uniform distribution of abrasive particles within the matrix of the selected matrix material.

8. The drill bit of claim **1**, wherein the first plurality of surface features have first diameters and the second plurality of surface features have second diameters, the first diameters being greater than the second diameters.

9. The drill bit of claim **8**, wherein the first radial distance is smaller than the second radial distance.

10. The drill bit of claim **1**, wherein, during rotation of the drill bit, the plurality of surface features of the at least one fixed segment are configured to apply variable contact stresses to a formation.

11. The drill bit of claim **1**, wherein the abrasive particles within the matrix of the selected matrix material are configured to cut material of a formation.

12. A drill bit, comprising:

a crown having a distal portion and defining a central axis, the crown comprising:

a first fixed segment formed in the distal portion of the crown and having a planar portion positioned transverse to the central axis of the crown and a plurality of first surface features continuous with and extending distally away from a portion of the planar portion of the first segment, a center point of the plurality of first surface features being positioned at a first radial distance from the central axis, wherein the plurality of first surface features are discontinuous and spaced apart within the first segment with respect to a first arced path defined by the first radial distance, wherein the plurality of first surface features and the planar portion of the first segment are integrally formed of a selected matrix material, the selected matrix material comprising a matrix and a plurality of abrasive particles within the matrix, wherein each surface feature of the first fixed segment consists solely of the selected matrix material; and

a second fixed segment formed in the distal portion of the crown and having a planar portion positioned transverse to the central axis of the crown and a plurality of second surface features continuous with and extending distally away from a portion of the planar portion of the second segment, a center point of the plurality of second surface features being positioned at the first radial distance from the central axis, wherein the plurality of second surface features are discontinuous and spaced apart within the second segment with respect to the first arced path defined by the first radial distance, wherein the plurality of second surface features and the planar portion of the second segment are integrally formed of the selected matrix material, wherein each surface feature of the first fixed segment consists solely of the selected matrix material, and

wherein the matrix of the selected matrix material is configured to erode to expose the abrasive particles within the matrix.

13. The drill bit of claim **12**, further comprising a radial gap defined between the first segment and the second segment.

14. The drill bit of claim **12**, wherein the first segment further comprises a plurality of third surface features positioned at a second radial distance from the central axis, the plurality of third surface features being discontinuous and spaced apart within the first segment with respect to a second arced path defined by the second radial distance, the second radial distance being greater than the first radial distance, wherein portions of the plurality of first and third surface features radially overlap.

15. The drill bit of claim **14**, wherein the plurality of first surface features have a diameter that is greater than a diameter of the plurality of third surface features.

16. The drill bit of claim **15**, wherein the second segment further comprises a plurality of fourth surface features positioned at the second radial distance from the central axis, the plurality of fourth surface features being discontinuous and spaced apart within the second segment with respect to the second arced path defined by the second radial distance.

17. The drill bit of claim **12**, wherein, during rotation of the drill bit, the plurality of first surface features and the plurality of second surface features are configured to apply variable contact stresses to a formation.

18. The drill bit of claim **12**, wherein the abrasive particles within the matrix of the selected matrix material are configured to cut material of a formation.

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